ASSESSMENT REPORT FOR THE OYSTER INDICATOR IN THE NORTHERN ESTUARIES

2008

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Eastern Oyster *Crassostrea virginica*

LOCATION	LAST STATUS[1]	CURRENT STATUS[2]	2-YEAR PROSPECTS[3]	CURRENT STATUS[2]	2-YEAR PROSPECTS[3]
Eastern Oyster					
Caloosahatchee Estuary	NA	🟡	🟡	The oysters in the Caloosahatchee Estuary are still being impacted by too much fresh water in summer and too little fresh water in the winter. Too much fresh water impacts reproduction, larval recruitment, survival and growth, while too little fresh water impacts the survival of oysters due to higher disease prevalence and intensity of *Perkinsus marinus* and predation. Current conditions do not meet restoration criteria, signifying that this area needs further attention.	Management objectives for regulating freshwater inflows play an important part in determining oyster success in the Caloosahatchee Estuary. If conditions remain constant, prognosis for the future will be stable. If the hydrological conditions remain the same, we do not expect to see an improvement in oyster responses in this estuary.
St. Lucie Estuary	NA	○	○	Insufficient data	Insufficient data
Loxahatchee Estuary	NA	○	○	Insufficient data	Insufficient data
Lake Worth Lagoon	NA	○	○	Insufficient data	Insufficient data
Lostman's River (Southern Estuaries)	NA	○	○	Insufficient data	Insufficient data

Stoplight Color Legend

- 🔴 Red – Substantial deviations from restoration targets creating severe negative condition that merits action.
- 🟡 Yellow – Current situation does not meet restoration targets and merits attention.
- 🟢 Green – Situation is good and restoration goals or trends have been reached. Continuation of management and monitoring effort is essential to maintain and be able to assess "green" status.
- ○ Blank - Insufficient data to infer trends.

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[1] Data in the last status column reflect data collected prior to calendar year 2000.
[2] Data in the current status column reflect data collected between calendar years 2000 – 2007.
[3] The following assumption is being used for the 2-year prospects column: there will be no changes in the water management from the date of the current status assessment.

KEY FINDINGS – EASTERN OYSTER

SUMMARY FINDING: On the whole, Eastern oyster status remained constant up to 2007. Given the duration of monitoring of this species, only Caloosahatchee Estuary had sufficient data to infer trends and status of this indicator. Monitoring in other estuaries (St. Lucie Estuary, Loxahatchee Estuary, and Lake Worth Lagoon) are on going, and will yield data to make trend and status assessments in the coming years. Current conditions in the Caloosahatchee Estuary show deviations from restoration targets, therefore restoration actions are merited. Status of oysters is expected to improve if hydrologic conditions are restored to more natural patterns.

KEY FINDINGS:

1. Preliminary results suggest that oyster status in the Caloosahatchee Estuary is the highest in the Northern Estuaries and remains stable. It should be cautioned that insufficient data exists for other estuaries to infer trends and make statistical comparisons.
2. There is too much freshwater inflow into the Caloosahatchee Estuary in the summer months and too little freshwater inflow into the estuary in the winter months, disrupting natural patterns and estuarine conditions. The oysters in the Caloosahatchee Estuary are still being impacted by this unnatural water delivery pattern. Too much fresh water impacts reproduction, larval recruitment, survival and growth while too little fresh water impacts the survival of oysters due to higher disease prevalence and intensity of *Perkinsus marinus* and predation.
3. Overall status of oysters in the Caloosahatchee Estuary is below restoration targets and requires action in order to meet restoration goals.
4. Oyster responses and population in the Caloosahatchee Estuary, while below targets, appear to be stable at this time and are expected to increase given proper hydrologic conditions through restoration.
5. Restoration of natural patterns (less freshwater flows in the summer and more freshwater flows in the winter) along with substrate enhancement (addition of cultch) is essential to improving performance of oysters in the estuaries.
6. Continued monitoring of oysters in the Caloosahatchee and other estuaries will provide an indication of ecological responses to ecosystem restoration and will enable us to distinguish between responses to restoration and natural variation.

Assessment Report for the Oyster Indicator in the Northern Estuaries 2008

Aswani K Volety, Patricia Sime, Patricia Goodman
and Kimberly Chuirazzi, Editors

Introduction

The Eastern oyster, *Crassostrea virginica*, is a dominant feature of the estuaries in South Florida. Oysters serve as an excellent indicator species for several reasons:

- Salinity and other water quality conditions suitable for oysters also produce optimal conditions for other desirable organisms.
- Oysters filter water and provide habitat, shelter and food for over 300 marine species.
- Crustaceans and fishes that reside in or visit oyster reef communities provide critical prey for larger fish and birds.
- Given the oyster's sedentary nature, it is easy to make cause-and-effect relationships between water quality and oyster health.
- Cause-and-effect relationships between oysters and stressors (water quantity, water quality and sediment loads) have been statistically correlated.
- Oysters are included in the project-level and regional scale modeling, monitoring and assessment efforts.

A system-wide monitoring and assessment plan (MAP) has been developed by the Restoration Coordination and Verification Program (RECOVER) of the Comprehensive Everglades Restoration Project (CERP) that describes the monitoring necessary to track ecological responses to restoration and how responses will be assessed (RECOVER 2004, 2006). Included in the MAP are descriptions of selected indicators, how these indicators are linked to key aspects of restoration, and performance measures that are representative of the natural and human systems found in South Florida. The MAP identified oysters as one of the indicators and established the performance measures described in this report.

Eastern Oyster, Crassostrea virginica

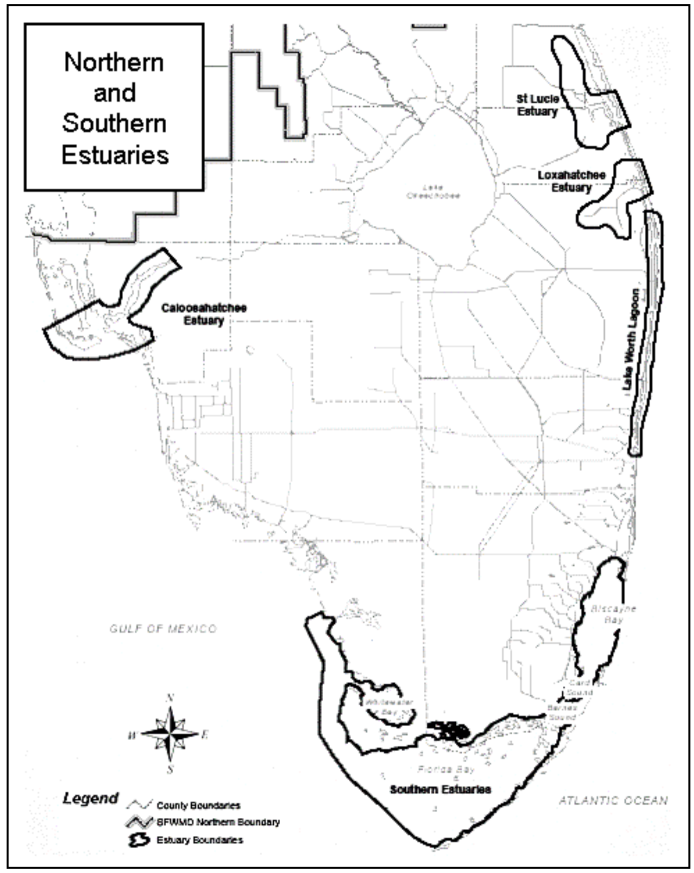


Figure 1. Location of Northern and Southern Estuaries in Florida.

Oysters have also been used as performance measures in many estuarine-linked CERP project plans. The cause-and-effect relationships are described in detail in estuarine conceptual ecological models (Barnes 2005, Sime 2005, Van Armen et al. 2005) and a Total System Conceptual Ecological Model (Ogden et al. 2005) developed by RECOVER. In addition, RECOVER has recommended the oyster be used as an indicator for interim goals (RECOVER 2005).

Oysters in South Florida

Caloosahatchee, Loxahatchee, Lake Worth Lagoon and St. Lucie Estuaries (Figure 1) are collectively referred to as the Northern Estuaries. In these estuaries, oysters have been identified as a "valued ecosystem component" (Chamberlain and Doering 1998a, b). Oysters are natural components of estuaries along the Gulf of Mexico and were abundant in the Northern Estuaries (RECOVER 2007). Currently, MAP oyster monitoring is conducted only in the Northern Estuaries.

Salinity is an important determinant of the distribution of oysters. Adult oysters normally occur at salinities between 10 and 30 parts per thousand (ppt), but they tolerate a salinity range of 2 to 40 ppt (Gunter and Geyer 1955). Occasional, short pulses of freshwater inflow can greatly benefit oyster populations by reducing predator and parasite impacts (Owen 1953), while excessive freshwater inflows may kill entire populations of oysters (Gunter 1953, Schlesselman 1955, MacKenzie 1977, Volety et al. 2003, Volety and Tolley 2005, Bergquist et al. 2006). Where salinities are between 15 and 20 ppt, populations are dense, reproductive activity is high, predator numbers are low, and spat recruitment and growth rates are high. Quality, quantity, timing and duration of freshwater flows have tremendous effect on oyster health, survival, growth and reproduction, and thus the biological responses of oysters are directly related to freshwater-influenced environmental conditions.

Water management and dredging practices have had a major impact on the historical presence, density and distribution of oysters. Historically, drainage patterns were characterized by gentle, meandering surface water flows through rivers, creeks, sloughs and overland sheet flow through contiguous marshy areas. This natural system absorbed floodwater, promoted ground water recharge, assimilated nutrients and removed suspended materials (ACOE and SFWMD 2002). As South Florida developed, the canal network worked too efficiently and drastically altered the quantity, quality, timing and distribution of fresh water entering the estuaries. Water management practices release significant volumes of fresh water over a short period of time, usually as flood releases, into the estuaries resulting in a sudden drop in salinity. This sudden drop can lead to significant mortality in the oyster population, and decreased growth, reproduction and spat recruitment. Freshwater releases during summer months cause flushing of oyster larvae to downstream locations that are unsuitable habitat. Also, undesirable shifts in the estuarine salinity envelope can result in increased susceptibility to disease. Additionally, flood releases and inland runoff contain numerous contaminants from urban and agricultural development. Inflows are too great in the wet season and too little in the dry season to support a healthy estuary.

The objectives of many CERP projects are focused on reducing these impacts. CERP projects that will restore more natural freshwater inflows into the estuaries will provide beneficial salinity conditions, a reduction in nutrient concentrations and loads, and improved water clarity, which will promote the reestablishment of healthy oyster bars. Healthy oyster bars will benefit other organisms that use this habitat during all or part of their life cycle.

Study Area

The Caloosahatchee Estuary was chosen as a model estuary to examine the impact of watershed alteration on oysters and to develop a stoplight report card for oyster physiologic and ecologic response. Figure 2 shows the oyster sampling sites within the Caloosahatchee Estuary. Oyster monitoring is also being conducted in the other Northern Estuaries and assessments for these will be presented in later assessment reports.

Spotlight Restoration Report Card

CERP projects are expected to moderate the stressors (i.e., freshwater discharges, diminished water quality and habitat loss) and enhance the natural attributes (i.e., oysters) of the Northern Estuaries. This will be accomplished through habitat enhancement, as well as water storage and treatment projects. As various CERP projects are implemented, changes in the hydrology, and thus, the biology of oysters will take place. A stoplight report card system that integrates various responses that are currently being measured as part of a monitoring plan can provide a powerful way to distinguish between restoration changes and natural patterns.

Using oyster responses, we have developed a stoplight report card for the Caloosahatchee Estuary based on CERP performance measures to grade an estuarine system's response to human impacts or restoration conditions. We expect to be able to distinguish between responses to restoration and natural patterns by ~ 2015 after more representative rainfall years (wet, dry and normal). The stoplight report card involves a suitability index score for each organism metric as well as a trend score (- decreasing trend, +/- no change in trend, and + increasing trend). Two questions are addressed using suitability curves: 1) Have we reached the restoration target? and 2) Are we making progress toward targets? Results are translated into a stoplight display showing the status of each component. A final oyster index score is obtained by taking the geometric mean of the components. For the Caloosahatchee Estuary, all the metrics are weighted equally in determining the overall score. In other systems, various responses may be dropped or weighted more or less, as appropriate. Stoplight colors indicate success (green), caution (yellow) or failure (red). In this initial assessment, only the Caloosahatchee Estuary is considered. Other estuaries will be included in future assessments.

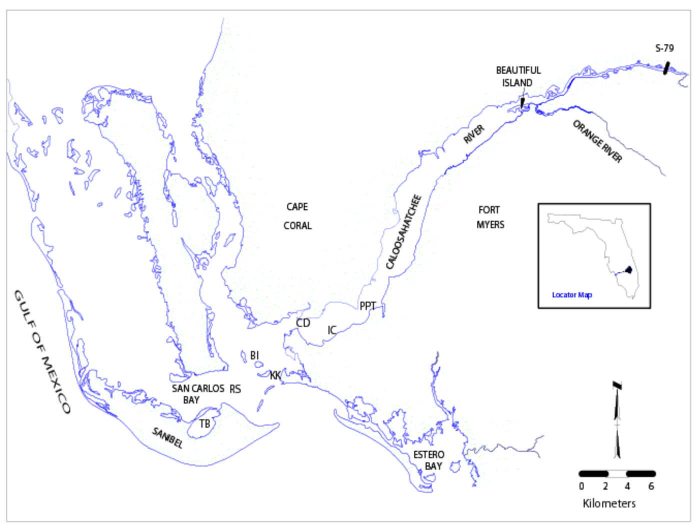


Figure 2. Oyster sampling locations within the Caloosahatchee Estuary. Locations (PPT = Pepper Tree Point, IC = Iona Cove, CD = Cattle Dock, BI = Bird Island and TB = Tarpon Bay) are from upstream to downstream along a salinity gradient.

Performance Measures

The stoplight restoration report card includes five metrics:

- Density of living oysters
- Condition index
- Gonadal index (reproductive activity)
- Spat (larval) recruitment
- Juvenile growth
- Disease prevalence and intensity

These metrics are correlated with hydrologic conditions including depth, flow, salinity, temperature, dissolved oxygen, season, spatial extent and water quality. Salinity is a critical parameter in estuarine habitats. Targets for oyster performance measures are based on patterns that are considered natural for estuaries along the east and west coast of Florida.

Stoplight scoring criteria for these performance measure metrics are presented in Tables 1a and 1b. A score of 1.0 is the restoration target. All performance measures are averages of 2-5 years data measured during appropriate seasons. The component score (e.g., living density) is the average of the suitability index score plus the trend. Table 2 shows how index ranges are translated into an index score.

Table 1a. Stoplight scoring criteria for suitability index.

Component	Score and Spotlight by Range		
	0	**0.5**	**1**
Living Density	0 - 200	>200 - 800	>800 - 4000
Condition Index	0 - 1.5	>1.5 - 3.0	>3.0 - 6.0
Gonodal Index	0 - 1	>1 - 2	>2 - 4
Spat Recruitment	0 - 5	>5 - 20	>20 - 200
Juvenile Growth	0 - 1	>1 - 2.5	>2.5 - 5
Perkinsus marinus Prevalence	>50 - 100	>20 - 50	0 - 20
P. marinus Intensity	>3 - 5	>1 - 3	0 - 1

Table 1b. Stoplight scoring criteria for trend index.

Component	Score and Spotlight by Range		
	0	**0.5**	**1**
P. marinus Intensity	>3 - 5	>1 - 3	0 - 1
Trend	- slope	no slope	+ slope

Table 2. Translation for converting suitability or trend index from Tables 1a and b into an index score and stoplight color.

Index Range	Index Score	Stoplight Color
0.0-0.3	0	Red
>0.3-0.6	0.5	Yellow
>0.6-1.0	1.0	Green

Water Quality

Methods

Water quality measurements were taken along with oyster sample collection. Temperature, salinity and dissolved oxygen were measured. Freshwater inflows into the Caloosahatchee Estuary from S-79 Lock and Dam were obtained from the South Florida Water Management District (SFWMD).

Results

As expected, temperatures at the sampling locations in the Caloosahatchee Estuary were higher during the warmer summer – early fall months (April – October) and were lower during the cooler drier months (November – March). In contrast, salinities at the sampling locations were lower during the summer – early fall months (June – October) and higher during the cooler months (November – May; results not shown). There was a significant relationship between flows and salinity at the five sampled locations (Figure 3). The influence of freshwater inflow into the system is more pronounced at the upstream locations compared to the downstream locations.

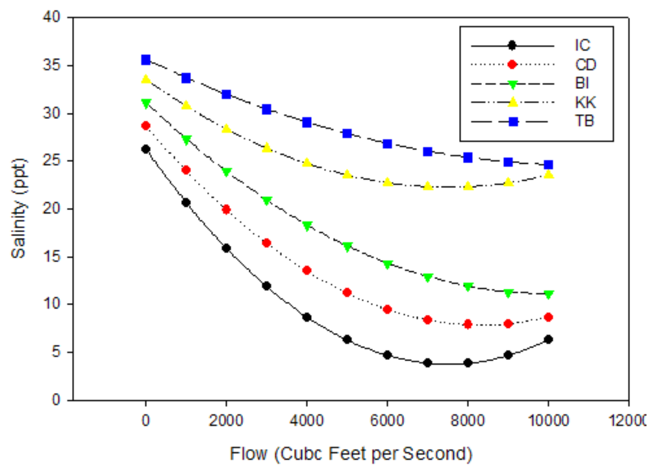


Figure 3. Relationship between freshwater inflow and salinities.

Oyster Density

Methods

Oyster living density, number of living oysters per square meter (oysters/m^2), was measured at the stations shown in Figure 2. Density is measured in the late fall and early spring. This period is the most ideal time for density measurement since oysters have reproduced for the year and spat have settled from the water column. Four 0.25-square meter quadrats were randomly located at the mean low tide height at each reef. The number of living oysters within each quadrat were counted and compared among reefs at various locations.

Results

Salinities are significantly affecting oyster living density. Too much freshwater in the summer months resulting in low salinities reduce the survival or spat and adult oysters at upstream locations. Oyster density ranged between 102 – 2,345 oysters/m^2 at various sampling locations. Mean density for the Caloosahatchee Estuary for the sampling period for

Oyster bar at low tide

which data is available is 765 – 1,795 oysters/m^2. Mean density for all the sampling locations in the estuary was a low of 765 ± 107 (2003) to a high of 1,795 ± 76 oysters/m^2 (2004).

Condition Index

Methods

The physiological condition of an oyster can be measured by its condition index, which is the ratio of meat weight to shell weight (Lucas and Beninger 1985). Although oysters tolerate salinities between 0-42 ppt, growth is maximized at salinities of 14-28 ppt. Slower growth, poor spat production, and excessive valve closure occur at salinities below 14 ppt (Shumway 1996). If an oyster is stressed either by water quality or by disease, it has less energy for growth and reproduction. Consequently, a comparison of oyster condition index among the oyster reefs along the salinity gradient is a good indication of oyster health and the influence of salinity and disease on this health. Oysters from an altered estuary having extreme salinities have significantly lower condition index compared to oysters from an unaltered estuary (Volety and Savarese 2001). Oysters were collected for condition determination monthly between August 1999 and January 2008 at the same time disease prevalence was surveyed.

Results

Annual average oyster condition index ranged between 2.4 and 3.4 (Figure 4). Condition index appears to be related to spawning and salinity conditions. Condition index varied significantly between sampling locations and between sampling months. Condition index in oysters was higher during the December – May period and was lowest in October. Condition index decreased from March – October, a period that coincides with oyster spawning.

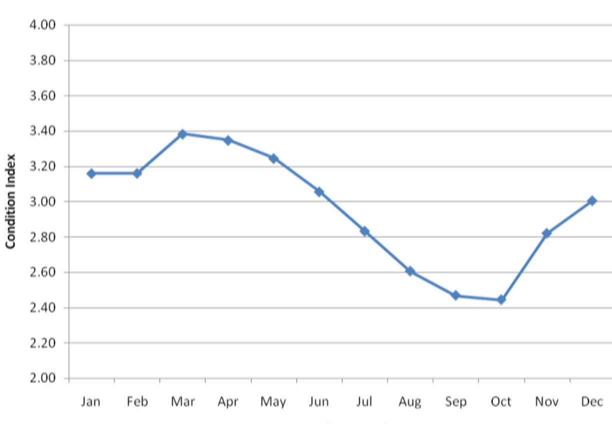
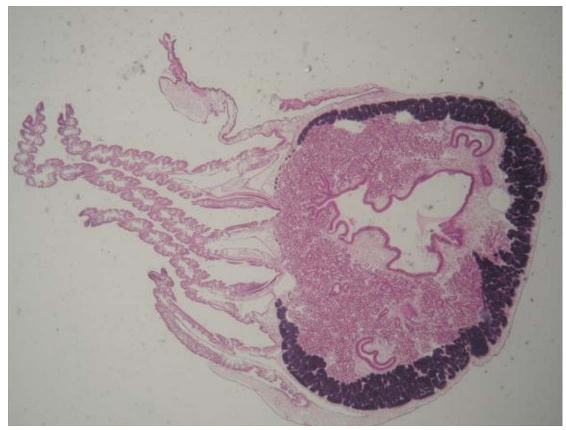


Figure 4. Mean condition index of oysters from all sampling locations in the Caloosahatchee Estuary.

Gonadal Index

Methods

Gonadal index (scale of 0-5) is a measure of the reproductive stage and spawning of oysters. Each month, 10 to 15 samples of oysters were collected from each sampling location between August 1999 and September 2007. Cross-sections of these oysters were made and viewed under a microscope. Gonadal portions of the sections were observed to determine gender and gonadal condition (Volety and Savarese 2001, Volety et al. 2003). The yearly average is used for the index.



Cross-section of an oyster viewed under a microscope used to determine gender and gonadal condition

Results

Salinity may be affecting gonadal condition of oysters, with low salinities detrimental to reproduction. The gonadal index was very cyclical and varied significantly between sampling locations and sampling months. It was higher during April – October, suggesting an active spawning of oysters and was lower during November – March months (Figure 5).

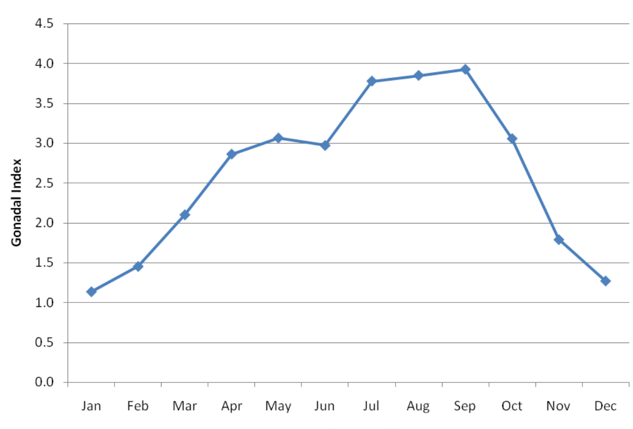
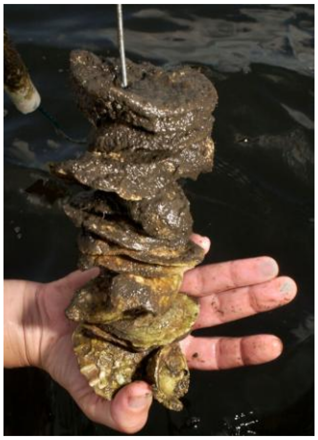


Figure 5. Mean gonadal stage of oysters from all the sampling locations in the Caloosahatchee Estuary.

Spat Recruitment

Methods

Oyster spat recruitment experiments were conducted using old adult oyster shells strung together by a weighted galvanized wire and deployed at sampling locations. A shell string consisting of 12 oyster shells, each 5.0-7.5 cm long, was suspended off the bottom at various sites (Haven and Fritz 1985). Oyster spat settlement was monitored monthly by counting the number of spat settled on the underside of strung shells. Spat settlement is expressed as the number of spat settled per oyster shell per month. Data was collected monthly from each of the sampling locations between August 1999 and January 2008.



Shell string used to conduct spat recruitment experiments

Results

Spat recruitment significantly affects oyster spat recruitment. High freshwater inflows and low salinities either result in mortality or flush the larvae to downstream locations where suitable substrate may not be available. Spat recruitment per shell ranged between 2.5 and 25. Spat recruitment of oysters varied significantly between sampling locations and sampling months. Recruitment of spat was higher between April – October, with peak recruitment occurring in August. Little or no spat recruitment was observed between November – March (Figure 6).

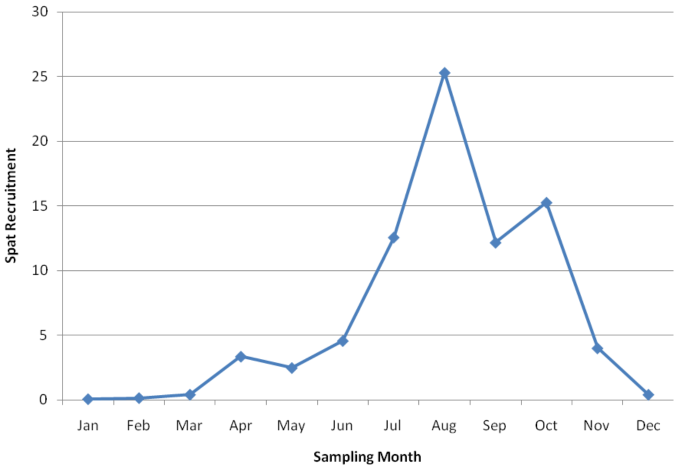


Figure 6. Mean spat recruitment (spat/shell) of oysters from all the sampling locations in the Caloosahatchee Estuary.

Juvenile Oyster Growth

Methods

One to two hundred juvenile oysters (10-20 mm) were deployed at all sampling locations in 0.5-mm closed and open wire mesh bags. Fifty randomly selected oysters were measured to the nearest 0.1 mm every month from each location. Juvenile oysters were placed in wire mesh bags to exclude predation and indicate growth and/or mortality due to water quality.

Results

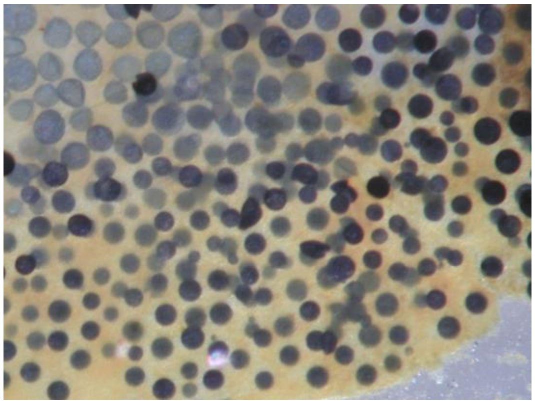
Juvenile oyster growth and survival was poor at the upstream locations given high freshwater inflows and low salinities during the summer months. Juvenile oyster growth (mm/month) and mortality varied widely between sampling locations and sampling months. Significant juvenile mortality was observed when oysters were deployed during the summer months when the salinities are typically low (results not shown). When oysters were deployed in late fall months (October – December), when salinities are higher, higher growth was observed at the upstream locations, which tended to have more estuarine salinities compared to downstream locations where the salinities are marine to hypersaline. Mortality rates were typically 60% - 100% depending on the salinity (results not shown).

Disease Prevalence and Intensity

Methods

Perkinsus marinus, a protozoan parasite, causes disease in oysters. Susceptibility to this disease of oysters along the salinity gradient within the Caloosahatchee Estuary was determined at six locations. A total of 10-15 oysters per location were collected monthly between August 1999 and January 2008.

The presence of *P. marinus* was determined by taking samples of gill and digestive sacs and incubating them for 4-5 days in a solution that will enlarge the *P. marinus* cells allowing for visual identification under a microscope (Ray 1954, Volety et al. 2000, Volety et al. 2003). Prevalence of infection was calculated as percent of infected oysters. The intensity of infection was recorded using a modified Mackin scale (Mackin 1962) in which 0 = no infection, 1 = light, 2 = light-moderate, 3 = moderate, 4 = moderate-heavy, and 5 = heavy.



Perkinsus marinus

Identification and measurement of organisms in oyster reefs

Results

P. marinus infection was significantly affected by freshwater inflows. Low salinities during the summer months and low temperatures during the winter months moderate the infection prevalence and intensities. Mean *P. marinus* prevalence from all the sampling locations and sampling months ranged between 31 and 66% (Figure 7) between sampling months and between 35 and 56% between sampling locations (results not shown). Similarly, *P. marinus* intensity ranged between 0.64 and 1.16 during various sampling months (scale 0-5; Figure 8) and between 0.41 and 1.1 at various sampling locations (results not shown). Disease prevalence and intensity increased with increasing salinity and distance downstream (results not shown). On average, disease prevalence and intensity was higher in January (when salinities tend to be higher) and during August (when temperatures tend to be the highest).

Discussion

Changes in average oyster condition index coincided with the reproductive phase of oysters. As oysters reproduce, gametes are shed resulting in a decrease in body mass and thus a reduced condition index. This trend is reinforced by the gonadal index of oysters as well as spat recruitment. Gonadal index of oysters was higher during the peak spawning months (April – October 8). Larval recruitment was observed at various sampling locations between April – October. Spat recruitment per shell is not limited by larval availability. Juvenile oysters grow faster than adult oysters, thus enabling the determination of growth rates at various locations subjected to various salinities. Given the amount of freshwater inflows into the Caloosahatchee Estuary (0 – >15,000 cfs), growth and survival of oysters was significantly impacted at the extreme end of the salinity range. Disease prevalence and intensity increased with increasing salinity and distance downstream (results not shown). On average, disease prevalence and intensity was higher in January when salinities tend to be higher and during August when temperatures tend to be the highest.

These results are used in the present study to develop an easy to understand Stoplight Report Card System to present the current state of oysters in the Caloosahatchee Estuary. In this case, the results are not used to examine the relationship between various water management practices and interrelationships between oyster responses and other factors that influence them.

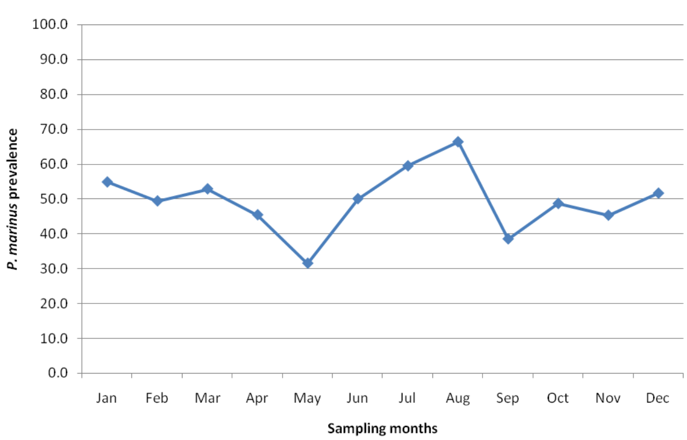


Figure 7. Mean prevalence of *P. marinus* (percent of infected oysters) from all the sampling locations in the Caloosahatchee Estuary.

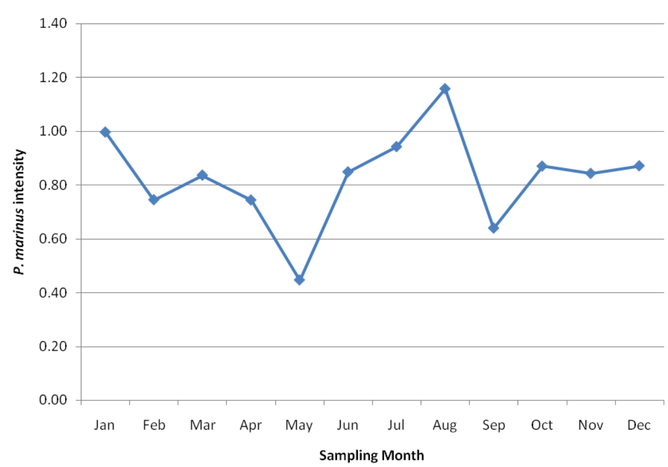


Figure 8. Mean intensity of *P. marinus* in oysters from all the sampling locations in the Caloosahatchee Estuary.

Final Stoplight Scores

Component stoplight scores and the overall oyster spotlight score based on the available data are presented in Table 3. The component scores were: living density = 0.75, condition index = 0.5, gonadal index = 0.75, spat recruitment = 0.5, juvenile growth = 0.5, *P. marinus* prevalence = 0.25, and *P. marinus* intensity = 0.5. Components yield a combined score for the location of 0.5. The oyster population within the Caloosahatchee Estuary is at a “caution” stage (yellow) indicating current conditions do not meet restoration criteria. This aeaa needs further restoration attention. Management objectives for regulating freshwater inflows play an important part in determining oyster success in the Caloosahatchee Estuary. If conditions remain constant, prognosis for the future will be stable.

Table 3. Component and overall spotlight scores for oysters in the Caloosahatchee Estuary

Component	Parameter Value	Parameter Value Stoplight	Index Score	Trend	Trend Stop light	Trend score	Average Component Score	Stoplight
Living Density (living oysters/m^2)	1029	🟢	1	±	🟡	0.5	(1+0.5)/2=0.75	🟢
Condition Index	2.96	🟡	0.5	±	🟡	0.5	(0.5+0.5)/2=0.5	🟡
Gonadal Index	2.61	🟢	1	±	🟡	0.5	(1+0.5)/2=0.75	🟢
Spat Recruitment (spat/shell)	6.43	🟡	0.5	±	🟡	0.5	(0+0.5)/2=0.5	🟡
Juvenile Growth (mm/month)	2	🟡	0.5	±	🟡	0.5	(0.5+0.5)/2=0.5	🟡
P. marinus Prevalence (% of infected oysters)	49.5	🟡	0.5	-	🔴	0	(0.5+0)/2=0.25	🔴
P. marinus Intensity	0.83	🟢	1	-	🔴	0	(1+0)/2=0.5	🟡
Geometric mean of oyster component scores (0.75 x 0.5 x 0.75x0.5 x 0.5 x 0.25 x 0.5)$^{1/7}$ = 0.508								
Final Eastern Oyster Index score = 0.5								🟡

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